



Sierra Nevada Network White Pine Monitoring

2014 Annual Report

Natural Resource Data Series NPS/SIEN/NRDS—2015/761



ON THE COVER

Krummholz whitebark pine (*P. albicaulis*) plot near Mount Clark, Yosemite National Park, California.
Photograph by B. Permar.

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Executive Summary

White pine tree species in Sequoia and Kings Canyon National Parks (SEKI) and Yosemite National Park (YOSE) are vulnerable to several stressors including invasive pathogens, native pests, and climate change, and have been recognized as a high priority vital sign for SIEN. Currently, populations of whitebark pine (*Pinus albicaulis*) and foxtail pine (*P. balfouriana*), as well as their respective plant communities, are in better ecological condition in the Sierra Nevada compared to populations in the Cascades and Rocky Mountains (Millar et al. 2012). However, the observed steeply declining trends in white pine populations in the northern Cascades and Rocky Mountains, coupled with the identification of key stressors in SIEN parks, is a significant cause for concern about the future status of these ecologically valuable communities. Monitoring white pine forest community dynamics will allow for early detection of downward trends and identify the potential need for management intervention. White pine monitoring in SIEN is being closely coordinated with monitoring of white pine in other networks (limber pine [*P. flexilis*] in the Upper Columbia Basin Network [UCBN]; whitebark pine in the Klamath Network [KLMN]), using a common monitoring protocol. Thus, information from this monitoring project will contribute meaningfully to the broader regional assessment of the status and trends of white pine species across western North America.

This report documents the results of the 2014 field season, which is the third year of monitoring in SEKI and YOSE. The 2014 goal was to establish the third of three rotating panels (panel 3) for each species-park population: YOSE-whitebark pine, SEKI-whitebark pine, and SEKI-foxtail pine. Each panel consists of 12 permanent 50 x 50 m (2,500 m²) plots that were randomly selected for each of the three populations. Thus, there will be a total of 36 whitebark pine plots in YOSE, 36 whitebark pine plots in SEKI, and 36 foxtail pine plots in SEKI. Data from plot surveys will be used to characterize white pine forest community dynamics in SEKI and YOSE, including changes in tree species composition, forest structure, forest health, and demographics.

During July 2014, the whitebark pine panel in YOSE was sampled. We established nine whitebark pine plots, rejected two, and partially installed one additional plot. From August to September, we worked on the foxtail and whitebark pine panels in SEKI. We established ten foxtail pine plots, ten whitebark pine plots and rejected three other whitebark plots. In total, the crew visited 35 sites during the 2014 field season and completed installation of 29 of them. Species composition, forest structure, and factors affecting tree health and reproduction including incidence and severity of white pine blister rust (*Cronartium ribicola*) infection, mountain pine beetle (*Dendroctonus ponderosae*) infestation, dwarf mistletoe (*Arceuthobium* spp.) infection, canopy kill, and female cone production were recorded.

In the nine completed YOSE whitebark pine plots, 1,242 live whitebark pine trees and 1,138 other conifers were sampled. An additional 35 dead trees were also sampled. Signs of white pine blister rust or dwarf mistletoe were not found, but there was one live lodgepole pine (*P. contorta*) that showed symptoms of mountain pine beetle activity. The average number of live whitebark pine trees per plot was 138 (SD = 190). Fourteen percent of live whitebark pine trees produced female cones. Whitebark pine seedling regeneration, averaged 4,568 (SD = 10,775) seedlings per hectare. This was largely driven by one krummholz plot that contained 265 seedlings within the nine seedling plots. Only three of the nine plots contained whitebark seedlings.

In the ten completed SEKI whitebark pine plots, 1,078 live whitebark pine and 591 other conifers were sampled. An additional 36 dead trees were also sampled. Indications of white pine blister rust or dwarf mistletoe were not found, but mountain pine beetle activity was recorded on one live lodgepole pine. The average number of live whitebark pine trees per plot was 108 (SD = 78). Twenty four percent of live whitebark pine trees produced female cones. Whitebark seedling regeneration averaged 1,716 (SD = 3,596) seedlings per hectare. The largest number of seedlings found in a plot was 94 and four of ten plots contained whitebark seedlings.

In the ten completed foxtail pine plots in SEKI, 221 live foxtail pine trees, 221 whitebark pine trees, and 99 other conifers were measured and tagged. Fifty-seven dead trees were also recorded. No signs of blister rust infection, mistletoe, or beetle activity were found. The average number of foxtail pine trees per plot was 21 (SD = 25). Seventy percent of the foxtail pine trees produced female cones. Only six foxtail seedlings and saplings were recorded within the regeneration plots for an average of 74 (SD = 167) foxtail seedlings per hectare. Only two of the ten plots contained foxtail seedlings. One plot, however, which was dominated by whitebark pine, contained 21 whitebark seedlings.

Based on this third season of monitoring, minor adjustments to the protocol and SOPs were made. Changes included measuring diameter at breast height (1.37 m) from side slope, better defining how the location of seedling plots was identified, and, unlike 2013, recently dead trees were recorded only as “RD” and no mortality year was estimated. Another change implemented in 2014 was that plots were rejected for steepness if plots had a slope >35 degrees (as opposed to >30 degrees in 2013). Thirty five degrees is the standard given in the protocol so this change was a return to the accepted standard.

Acknowledgments

Funding for this project was provided through the National Park Service Natural Resource Challenge and the Service-wide Inventory and Monitoring Program. I want thank the park superintendents and resource staff who made time to discuss park management objectives and information needs. Park staff also provided valuable logistical support to field operations in 2014. The initial high-elevation white pine monitoring annual report (Stucki et al. 2012) on which this document is based was developed by Devin Stucki, Tom Rodhouse, and Shawn McKinney. Tom Rodhouse and Erik Jules, and Linda Mutch also provided valuable comments that helped improve the report. I also want to thank Sarah Hoff, Sean Auclair, Roxanne Kessler, and Brie Permar for their stellar efforts in gathering the data presented in this publication.

Background and Objectives

Many western North American coniferous forests are currently facing unprecedented health challenges, including upsurges of native pests and pathogens, invasive exotic species, and altered disturbance regimes. Increased atmospheric warming, carbon dioxide concentration, and nitrogen deposition, as well as changes in precipitation patterns (i.e., timing, magnitude, and type) pose additional short- and long-term changes in high elevation forest ecosystem processes. Each factor alone can alter forest structure, function, and species composition, and additive or synergistic effects are likely if multiple agents act jointly. How forest ecosystems will respond to modern perturbations is uncertain. However, the magnitude of change in structure, composition, and key ecological processes will likely be exceptional. Indeed, increased tree mortality rates over the last several decades have recently been documented across a broad range of latitude and forest types in western North America (van Mantgem et al. 2009), which may have important consequences for forest stand dynamics and ecosystem functions.

Five-needle white pines (Family Pinaceae, Genus *Pinus*, Subgenus *Strobus*), and in particular whitebark pine (*Pinus albicaulis*), limber pine (*P. flexilis*), and foxtail pine (*P. balfouriana*) are foundational species (Tomback and Achuff 2010) in upper subalpine and treeline forests of several National Park Service (NPS) Pacific West Region (PWR) parks, including Sequoia and Kings Canyon National Parks (SEKI) and Yosemite National Park (YOSE) (Figure 1). Ongoing declines of foundation tree species pose an especially compelling problem because these species provide fundamental structure to ecosystems and are therefore irreplaceable (Ellison et al. 2005). If a foundation tree species is lost from these systems, it will likely lead to a cascade of secondary losses, shifts in biological diversity, and ultimately affect the functioning and stability of the community (Ebenman and Jonsson 2005).

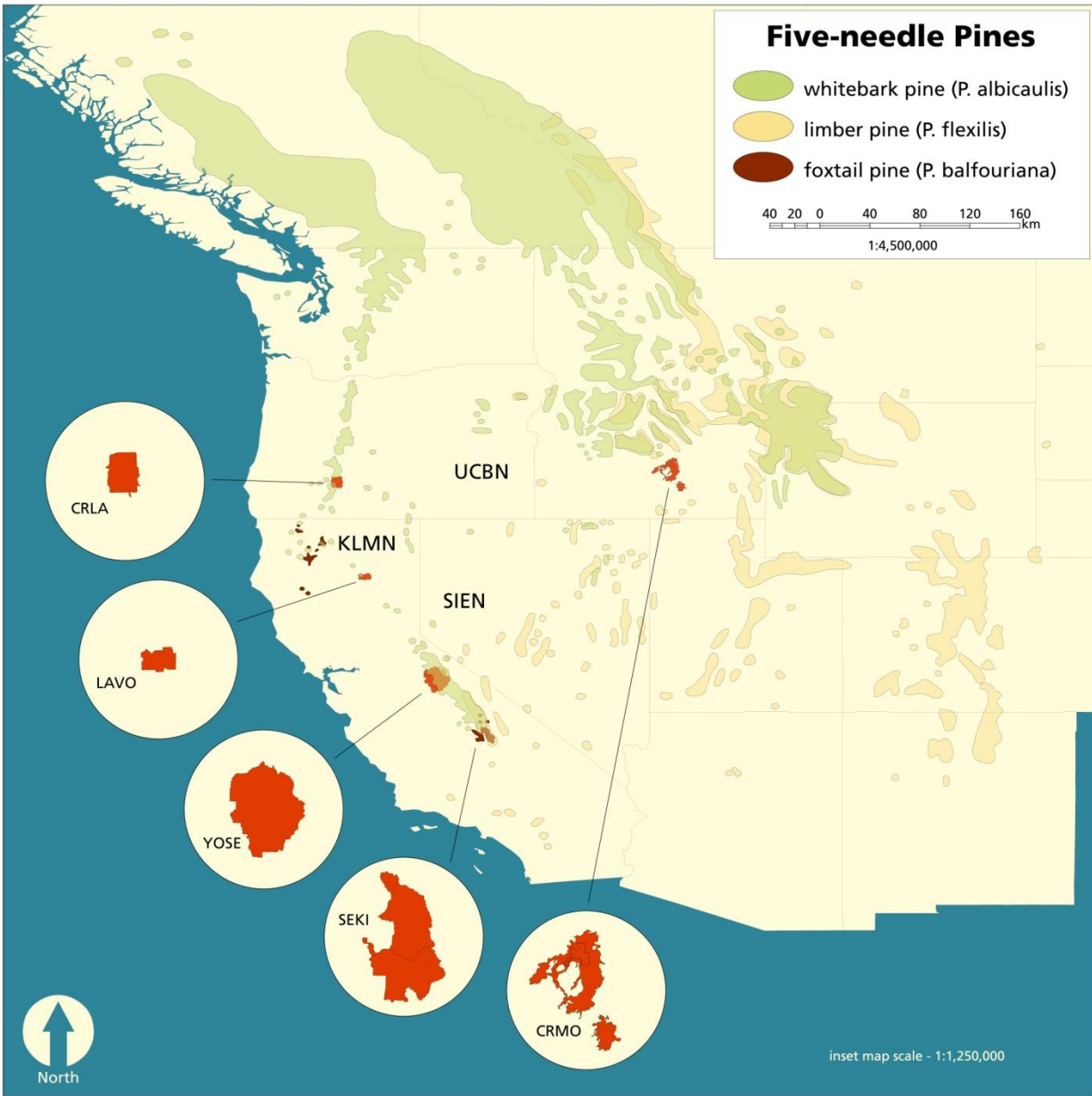


Figure 1. Distribution of whitebark pine, limber pine, and foxtail pine (from Little 1971) and locations of three Pacific West Region networks and associated parks.

Whitebark Pine

Whitebark pine occurs across a broad geographic range, reaching its southern limit in central California in the Mount Whitney vicinity and occurs on both the west and the more arid east side of the Sierra Nevada crest. Throughout its range, whitebark pine can occur in the montane, upper subalpine, and treeline zones (Arno and Hoff 1990; 1,370–3,660 m above sea level rangewide). It often occurs as the only tree species on the coldest and driest sites near treeline (Figure 2) and as a seral species on protected, slightly lower sites more favorable to its shade-tolerant competitors (Arno and Weaver 1990).



Figure 2. Whitebark pine near Charlotte Creek, Kings Canyon National Park. Photo taken by SIEN forest crew, August 2014.

In the Pacific West Region (PWR), whitebark pine is scattered across tens of thousands of hectares in the high elevations of SEKI and YOSE (Figure 1). White pine blister rust (*Cronartium ribicola*) infections on whitebark pine decrease from north to south in the PWR, resembling the trend seen in the Rocky Mountains. Blister rust is relatively rare in SEKI and YOSE when compared to northern portions of the PWR (e.g., North Cascades). Mountain pine beetles (*Dendroctonus ponderosae*) are currently abundant in the northern Cascades, but also decrease with latitude (Gibson et al. 2008) in the PWR.

Whitebark pine acts as a foundation species in high-elevation forest communities by regulating ecosystem processes, community composition and dynamics, and by influencing regional biodiversity (Ellison et al. 2005, Tomback and Kendall 2001). Whitebark pine plays a role in initiating community development after fire, influencing snowmelt and stream flow, and preventing soil erosion at high elevations (Tomback et al. 2001, Farnes 1990). The large, wingless seeds of whitebark pine are high in fats, carbohydrates, and lipids and provide an important food source for many granivorous birds and mammals (Tomback and Kendall 2001). Whitebark pine is a coevolved mutualist with Clark's nutcracker (*Nucifraga columbiana*), and is dependent upon nutcrackers for dispersal of its seeds (Tomback 1982, McKinney et al. 2009).

Foxtail Pine

Foxtail pine is endemic to two distinct areas in California, the Klamath Mountains in the northwest part of the state and the southern Sierra Nevada (Figure 1). Research on community and population dynamics is lacking for foxtail pine compared to whitebark pine. Foxtail pine occurs in four different forest types: 1) stands dominated by foxtail pine, 2) stands with foxtail pine and whitebark pine, 3) stands with foxtail pine and red fir (*Abies magnifica*), and 4) stands with foxtail pine, red fir, and western white pine (*P. monticola*) (Eckert and Sawyer 2002). Foxtail and whitebark pine overlap in some portions of their southern Sierra Nevada distribution, however, in many areas of the southern Sierra Nevada, foxtail pine is the major (sometimes exclusive) subalpine and treeline tree species (e.g., >3,000 m). Foxtail pine provides important habitat and food resources for birds and mammals, and influences snow melt and soil erosion (Figure 3).

The southern population of foxtail, subspecies *austrina*, provides important data for dendrochronological research on paleoclimate (Lloyd 1997) as a consequence of its great longevity (> 1,000 years) and slow growth. In fact, five-needle pines, in general, have proven valuable in enhancing our understanding of past climates through dendrochronological investigations (e.g., Kipfmüller and Salzer 2010, Woodhouse et al. 2011).



Figure 3. Foxtail pine near Red Spur, Sequoia National Park. Photo taken by R. Kessler, July 2014.

Objectives

At least three networks in the Pacific West Region identified white pine species as targets for long-term monitoring (Sarr et al. 2007, Mutch et al. 2008, Garrett et al. 2007). Ecologists in these networks (Klamath Network [KLMN], SIEN, and Upper Columbia Basin Network [UCBN]) collaborated to devise a common set of monitoring objectives and procedures which are documented in our multi-network white pine monitoring protocol (McKinney et al. 2012a, 2012b). The anticipated impacts from blister rust, dwarf mistletoe, mountain pine beetle, and climate change on high-elevation pines were primary factors considered by the monitoring objectives. Key demographic parameters within white pine forest communities will be estimated by monitoring individual trees within permanent plots. Specific objectives of white pine monitoring are to detect status and trend in:

1. Trees species composition and structure
2. Tree species birth, death, and growth rates
3. Incidence of white pine blister rust and level of crown kill
4. Incidence of bark beetles
5. Incidence of dwarf mistletoe
6. Cone production of white pine species

Methods

This section summarizes the methods used for white pine monitoring in SIEN. A full description of methods and standard operating procedures may be found in the multi-network white pine monitoring protocol (McKinney et al. 2012a, 2012b). Specific deviations from the published methods or clarifications on how the methods were interpreted in the field during the 2014 field season are documented in Appendix 1.

Sampling Frame

The sample frames for each species-park population (SEKI-whitebark pine, SEKI-foxtail pine, and YOSE-whitebark pine) were based on the distribution of whitebark and foxtail pine as identified in the YOSE and SEKI vegetation maps (Figures 4 – 6). An ordered list of plot locations was generated using a randomized, spatially-balanced sampling design via the Generalized Random Tessellation Stratified (GRTS) algorithm (Stevens and Olsen 2004). Plots in the ordered list were assigned to one of three panels and each panel will be sampled on a rotating basis every three years. Extra plot locations were drawn in the event that plots from the original sample draw were rejected (the oversample). Common reasons for rejection included 1) plots were on slopes too steep to be safely sampled (slopes ≥ 35 degrees), 2) sites were not accessible in a safe manner, and 3) sampling frame errors (i.e., plot did not contain the target vegetation type). Based on this sampling design, our scope of inference extends broadly across mapped stands of whitebark and foxtail pine on < 35 -degree slopes within YOSE and SEKI.



Sequoia and Kings Canyon National Parks

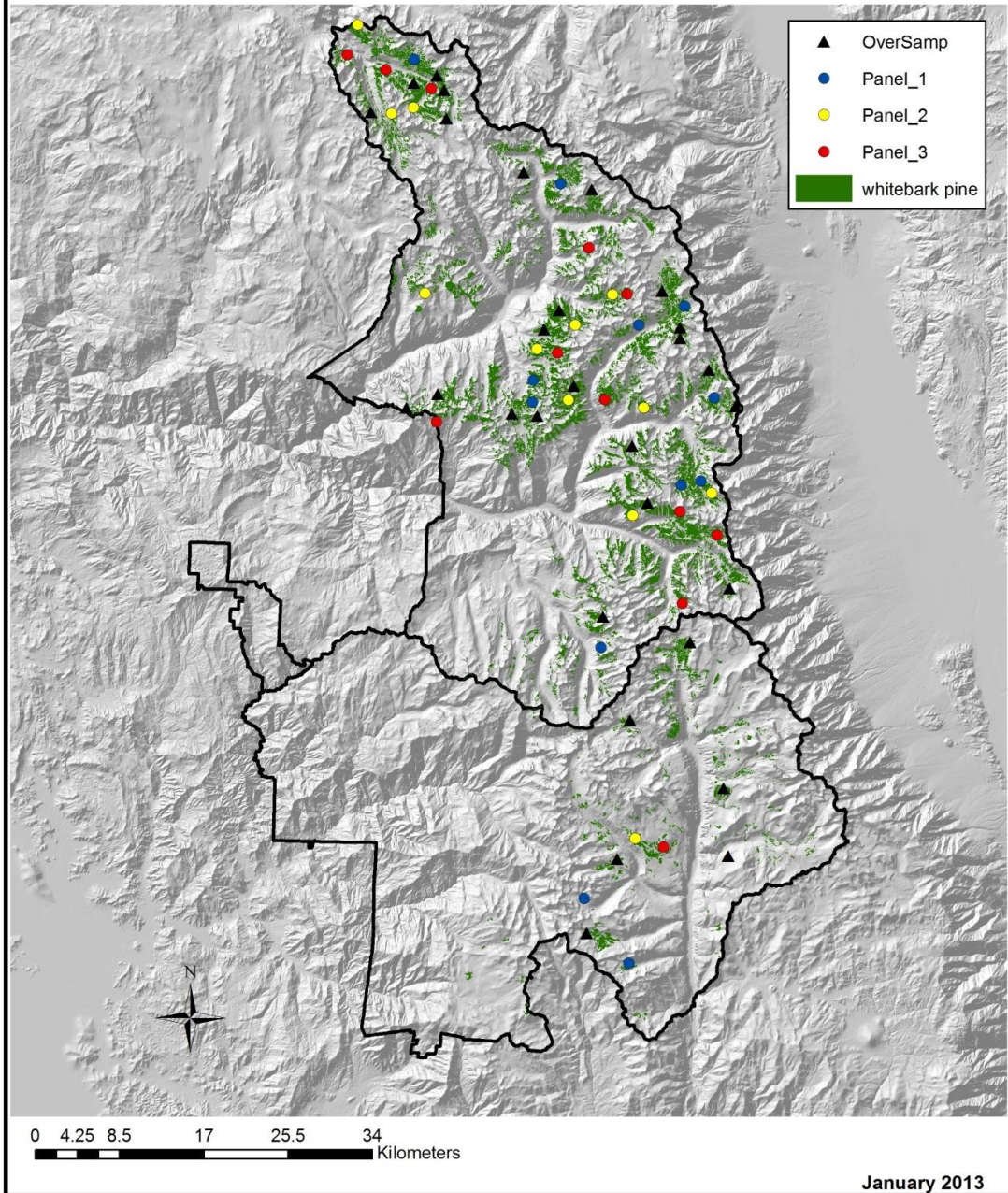


Figure 4. Whitebark pine sampling frame (green shading) and GRTS-based plot locations for Sequoia and Kings Canyon National Parks (colored dots). Plots are assigned to one of three panels (12 plots each), which are sampled every three years, or the oversample.



Sequoia and Kings Canyon National Parks

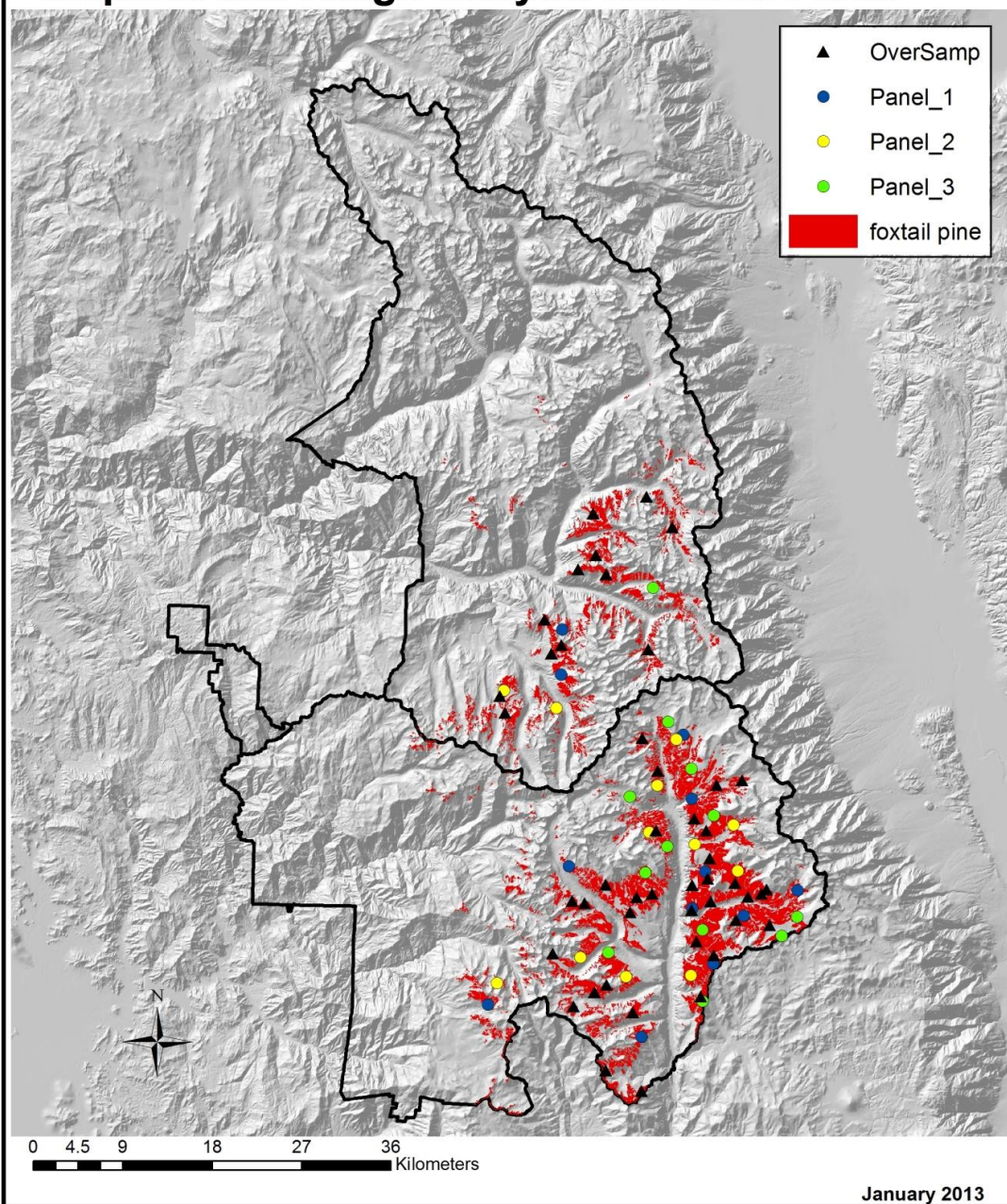


Figure 5. Foxtail pine sampling frame (red shading) and GRTS-based plot locations for Sequoia and Kings Canyon National Parks (colored dots). Plots are assigned to one of three panels (12 plots each), which are sampled every three years, or the oversample.



Yosemite National Park

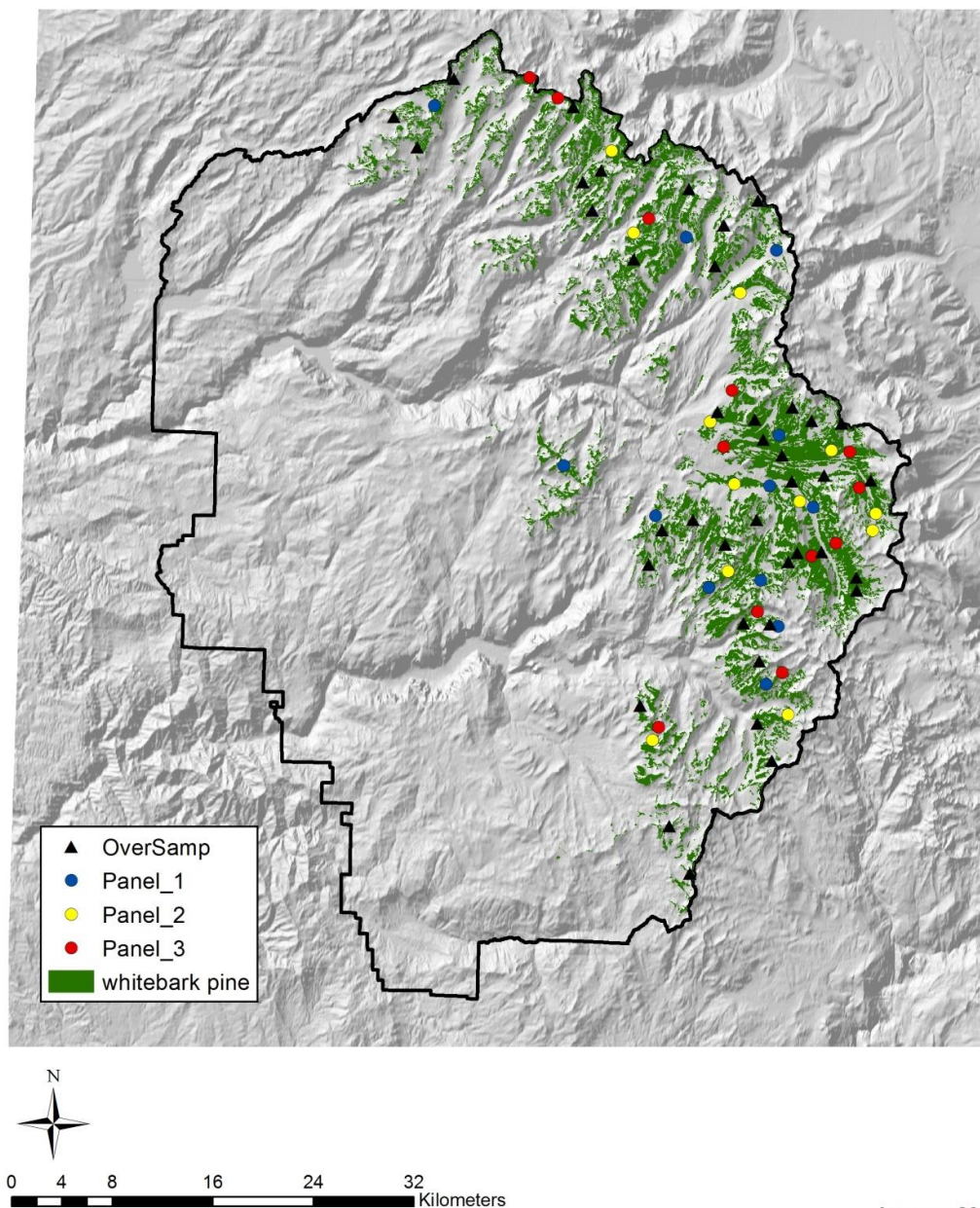


Figure 6. Whitebark pine sampling frame (green shading) and GRTS-based plot locations for Yosemite National Park (colored dots). Plots are assigned to one of three panels (12 plots each), which are sampled every three years, or the oversample.

Frequency and Timing of Sampling

We adopted a three-year rotating panel design for re-surveying permanent plots in SEKI and YOSE. Sampling will occur between June and October and each plot will be surveyed once per three-year rotation (McDonald 2003; Table 1). A total of 36 plots will be monitored in each park (YOSE and SEKI) for each species, resulting in an overall total sampling effort of 72 plots in SEKI (36 whitebark and 36 foxtail) and 36 plots in YOSE (whitebark only).

Table 1. Revisit design for monitoring white pine species in the Sierra Nevada Network. This panel design is followed for each of the 3 species-park populations (YOSE-whitebark pine, SEKI-whitebark pine, and SEKI-foxtail pine) for a total SIEN $n = 108$ plots. No sampling was conducted in 2012.

Panel	Year												
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1 ($n = 12$)	x				x			x			x		
2 ($n = 12$)		-	x			x			x			x	
3 ($n = 12$)				x			x			x			x

Plot Layout

Quarter hectare (50 x 50 m) macroplots consisting of five subplots are used to measure and track forest demographic parameters, disease, and insect occurrence, and the magnitude of their impact (Figure 5). The response design for this protocol is compatible with the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem* (GYWPMWG 2007) but differs in some respects, most notably, plot size. The 10 x 50 m plot size from the Yellowstone protocol has been increased to accommodate the often sparse distribution of white pines in our PWR parks and to adequately address forest demographic objectives. This design effectively represents five parallel 10 x 50 m subplots as used in the GYWPMWG and as proposed by the Whitebark Pine Ecosystem Foundation (Tomback et al. 2005).

A total of nine square regeneration plots (3 x 3 m) are established within each macroplot to measure seedling regeneration (Figure 7). Regeneration plots are located at each corner (4), at each midpoint between corners (4), and in the middle (1) of the macroplot (Figure 7). The current design was chosen because it provides a reasonable balance among sampling time constraints, observer accuracy and precision, and total area sampled.

absence of mistletoe for each third of a tree using the Hawksworth (1977) rating system. The level of canopy kill in live trees (see Appendix 1 for further details on canopy kill estimates) is determined by dividing the tree's canopy (all the main branches, encompassing all foliage and supporting twigs and side branches) into thirds and obtaining an ocular estimate of the percentage of each third of the canopy that is dead. Cone production is recorded based on whether female cones are present or absent on each live whitebark or foxtail pine tree. Live seedlings are tallied by species and height class in regeneration plots (Figure 8). Height classes are: 1) 20 to <50 cm, 2) 50 to <100 cm, and 3) 100 to <137 cm. Seedlings <20 cm are not measured.



Figure 8. Forest crew members Sean Auclair and Roxanne Kessler flag individual whitebark pine seedlings in a tree-line krummholz plot near Helen Lake, Yosemite National Park. Photo by J. Nesmith (June 2014).

Table 2. Relationship among measured variables, data, and objectives for long-term monitoring of white pine communities in the Pacific West Region. (p/a) indicates presence/absence.

Variable	Raw Data	Summarized Data	Objectives Addressed
Species	Tree (nominal)	Trees per hectare (TPH); all spp., each spp., proportion of total by spp.	1. composition & structure
Diameter	Tree (cm)	Basal area (m ² /ha); all spp., each spp., proportion of total by spp. Mean diameter (cm) by spp. Diameter classes (5 cm); proportion and TPH by spp.	1. composition & structure 2. growth rate
Height	Tree (m)	Mean ht. (m); all spp. and by each spp. Height classes (3 m); proportion and TPH by spp.	1. composition & structure 2. growth rate
Status	Tree (live or dead)	Proportion live and dead; all spp and by each sp. TPH and proportion by 5 cm diameter classes in each condition; all spp and by each sp.	2. birth and death rates
Crown kill	Each of three parts of a tree (%)	Mean (%); individual white pine trees.	3. level of crown kill
Active canker	Each of three parts of a tree (p/a)	Proportion and TPH with active cankers by each white pine sp.	3. rust infection incidence
Inactive canker	Each of three parts of a tree (p/a)	Proportion and TPH with inactive cankers by each white pine sp.	3. rust infection incidence
Rust infection	Tree (p/a of active <u>or</u> inactive canker)	Proportion and TPH infected and healthy by each white pine sp. TPH by 5 cm diameter classes in each condition by each white pine sp.	3. rust infection incidence
Bark beetle	Tree (p/a)	Proportion and TPH with beetle sign; all spp and each sp.	4. incidence of bark beetle
Dwarf mistletoe	Tree (p/a)	Proportion and TPH with mistletoe sign; all spp and each sp.	5. incidence of dwarf mistletoe
Female cones	Tree (p/a)	Proportion and TPH with cones by each white pine sp.	6. cone production
Seedlings	9 m ² plot; number of each of three size classes by species	Mean (number per m ²); all spp and each sp for each size class.	1. composition & structure 2. birth rates

2014 Sampling Logistics

A four-person crew was hired to establish and sample up to 36 plots within YOSE and SEKI during the 2014 field season. Training occurred over a one-week period in June at SEKI and included training on forest pathology by the SIEN Ecologist, safety and back-country communication, and project-specific training by SIEN and SEKI RMS staff. A two-day wilderness first aid class was also provided to the crew by SOLO. Field work occurred at YOSE in June and July and at SEKI in August and September. Detailed notes for each trip and route

descriptions were recorded by the crew and will be used in future years to help guide planning. For a complete list of plot status and location see Appendix 2.

Results

YOSE

Summary statistics for the YOSE whitebark pine plots are provided in Table 3. From June 18 to July 21, 2014, 12 plots were visited throughout whitebark pine stands in YOSE. Of these, installation was completed for nine; two were rejected because there were no whitebark pine trees within the plot boundaries, and one was established, but not completed. The nine completed plots contained a total of 2,415 trees: 1242 live whitebark pine (3 dead), 858 live lodgepole pine (20 dead, 9 recently dead), and 280 live mountain hemlock (*Tsuga mertensiana*) (2 dead, 1 recently dead). For the live whitebark pine trees, 81% displayed a krummholz growth form and the average number of stems per clump was 2.3 (range = 2 to 5). No indication of white pine blister rust, dwarf mistletoe, or beetle activity was found on whitebark pine within the nine established plots in YOSE, but there was one lodgepole pine that showed signs of mountain pine beetle infestation. The average number of live whitebark pine trees per plot (2500 m²) was 138 with a range of 4 to 538 trees. Approximately 14% of live whitebark pine trees ($n = 169$) produced female cones. Whitebark pine seedling regeneration was high, averaging 4,568 (SD = 10,774) seedlings per ha due to a high number of tallied seedlings within one plot ($n = 265$).

Table 3. Summary statistics on whitebark pine plots installed at YOSE in 2014 ($n = 9$).

	Average (SD)	Range
<i>P. albicaulis</i> density (trees/ha)	552 (759)	16 – 2152
Other species density (trees/ha)	506 (547)	4 – 1256
Snag density (dead trees/ha)	16 (27)	0 – 84
<i>P. albicaulis</i> DBH (cm)	5.9 (4.1)	1.4 – 12.3
Other species DBH (cm)	11.5 (10.4)	0.6 – 30.5
Snag DBH (dead tree cm)	19.5 (13.5)	1.2 – 37.5
<i>P. albicaulis</i> Basal Area (m ² /ha)	1.9 (2.4)	<0.1 – 7.8
Other species Basal Area (m ² /ha)	24.1 (26.6)	<0.1 – 63.8
Snag Basal Area (dead tree m ² /ha)	0.9 (1.6)	0 – 4.9
<i>P. albicaulis</i> blister rust infection rate (# of infected trees/ha)	0	0
Dwarf mistletoe infection rate (# of infected trees/ha)	0	0
Mountain pine beetle infestation rate (# of infested trees/ha)	0.4 (1.3)	0 – 4
<i>P. albicaulis</i> seedling regeneration 20-136 cm (seedlings/ha)	4568 (10775)	0 – 32716
Other species seedling regeneration 20-136 cm (seedlings/ha)	480 (742)	0 – 2222
<i>P. albicaulis</i> female cone production (# of trees with cones/ha)	110.7 (152.0)	0 – 416

SEKI

From July 28 to September 14, 2014, we visited thirteen plots in the SEKI-whitebark pine population and ten plots in the SEKI-foxtail pine population.

Whitebark Pine

Of the 13 whitebark plots that were visited, ten were fully installed and three were rejected due to steep slopes or lack of target species. Summary statistics are provided in Table 4. The ten fully installed whitebark plots contained a total of 1705 trees: 1078 live whitebark (22 dead, 1 recently dead), 580 live lodgepole (6 dead, 4 recently dead), 10 live western white pine, and 1 live mountain hemlock. There were also 3 dead trees of unidentified species. Of the 1078 live whitebark pines, 288 (27%) displayed a krummholz growth form. For trees that were multi-

stemmed, the average number of trees per clump was 2.5 (range = 2 to 7). No whitebark pine trees had signs of blister rust infection, beetle activity, or dwarf mistletoe within the sampling areas, but signs of mountain pine beetle activity were recorded on one live lodgepole pine. The average number of whitebark pines per plot was 108 (SD = 78) with a range of 23 to 250. Twenty-four percent of whitebark pine trees ($n = 253$) produced female cones in 2014. There were 139 whitebark pine seedlings (20-100 cm) recorded in the plots, resulting in an estimated 1716 (SD = 3596) seedlings per hectare.

Table 4. Summary statistics on whitebark pine plots installed at SEKI in 2014 ($n = 10$).

	Average (SD)	Range
<i>P. albicaulis</i> density (trees/ha)	431 (314)	92 – 1000
Other species density (trees/ha)	236 (473)	4 – 1536
Snag density (dead trees/ha)	14 (18)	0 – 52
<i>P. albicaulis</i> average DBH (cm)	10.1 (7.4)	1.6 – 28.5
Other species average DBH (cm)	13.8 (11.9)	0 – 34.7
Snag average DBH (dead tree cm)	16.2 (16.6)	0 – 45.3
<i>P. albicaulis</i> Basal Area (m ² /ha)	6.8 (7.7)	0.1 – 21.9
Other species Basal Area (m ² /ha)	13.2 (21.3)	0 – 55.3
Snag Basal Area (dead tree m ² /ha)	0.9 (1.3)	0 – 3.6
<i>P. albicaulis</i> blister rust infection rate (# of infected trees/ha)	0	0
Dwarf mistletoe infection rate (# of infected trees/ha)	0	0
Mountain pine beetle infestation rate (# of infested trees/ha)	0.4 (1.3)	0 – 4
<i>P. albicaulis</i> seedling regeneration 20-136 cm (seedlings/ha)	1716 (3596)	0 – 11605
Other species seedling regeneration 20-136 cm (seedlings/ha)	160 (349)	0 – 988
<i>P. albicaulis</i> female cone production (# of trees with cones/ha)	101 (89)	0 – 256

Foxtail Pine

All ten of the foxtail plots that were visited were fully installed. Summary statistics are provided in Table 5. The ten foxtail pine plots contained a total of 598 trees: 221 live foxtail pine (35 dead), 221 live whitebark pine (2 recently dead, 9 dead), 96 live lodgepole pine (4 recently dead), and 3 live western white pine. There were also 7 dead trees of unidentified species. No trees were found to have signs of blister rust infection, beetle activity, or dwarf mistletoe within the sampling areas. The average number of foxtail pines per plot was 22 (SD = 25) with a range of 1 to 86. Seventy percent of foxtail pine trees ($n = 154$) produced female cones in 2014. There were six foxtail pine seedlings (20-100 cm) recorded in the plots, resulting in an estimated 74 (SD = 167) seedlings per hectare.

Table 5. Summary statistics on foxtail pine plots installed at SEKI in 2014 (n = 10).

	Average (SD)	Range
<i>P. balfouriana</i> density (trees/ha)	88 (99)	4 – 344
<i>P. albicaulis</i> density (trees/ha)	88 (175)	0 – 524
Other species density (trees/ha)	40 (106)	0 – 340
Snag density (dead trees/ha)	23 (17)	0 – 56
<i>P. balfouriana</i> DBH (cm)	56.4 (31.3)	2.9 – 110.1
<i>P. albicaulis</i> DBH (cm)	19.4 (28.0)	2.4 – 69.1
Other species DBH (cm)	24.2 (22.0)	1.5 – 54.4
Snag DBH (dead tree cm)	61.7 (20.0)	32.2 – 98.7
<i>P. balfouriana</i> Basal Area (m ² /ha)	25.5 (21.6)	<0.1 – 64.0
<i>P. albicaulis</i> Basal Area (m ² /ha)	1.6 (3.6)	0 – 11.3
Other species Basal Area (m ² /ha)	2.9 (6.8)	0 – 21.9
Snag Basal Area (dead tree m ² /ha)	7.3 (5.9)	0 – 18.0
<i>P. balfouriana</i> blister rust infection rate (# of infected trees/ha)	0	0
Dwarf mistletoe infection rate (# of infected trees/ha)	0	0
Mountain pine beetle infestation rate (# of infested trees/ha)	0	0
<i>P. balfouriana</i> seedling regeneration 20-136 cm (seedlings/ha)	74 (167)	0 – 494
<i>P. albicaulis</i> seedling regeneration 20-136 cm (seedlings/ha)	259 (820)	0 – 2593
Other species seedling regeneration 20-136 cm (seedlings/ha)	0	0
<i>P. balfouriana</i> female cone production (# of trees with cones/ha)	62 (52)	0 – 168

Summary

Our 2014 data suggest that the whitebark pine and foxtail pine populations in areas sampled during the 2014 field season within SEKI and YOSE currently have no incidence of white pine blister rust or dwarf mistletoe, and a very low incidence of mountain pine beetle. These results are consistent with the 2011 and 2013 panel 1 and 2 data and other limited data on whitebark and foxtail pine collected in SEKI (Duriscoe and Duriscoe 2002). These results contrast sharply with whitebark pine health conditions in the Cascade and Rocky Mountain regions where infection rates of sampled trees have been recorded in excess of 80% (GYWPMWG 2010, Bockino and Tinker 2012). Information gathered from this white pine monitoring project will be integral to providing a more comprehensive understanding of the populations within SIEN parks as well as providing for comparisons across broader geographic areas. It will also allow early detection of important changes in populations that may require management intervention. This information will be particularly powerful if incorporated into an adaptive management framework, where it can be used to formulate sound, science-based management decisions at the park- or regional-level.

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Appendix 1. Notes on Field Methods

Certain procedures in the protocol sampling methods were ambiguous (i.e., plot and tree level measurements), and crews had to resolve them while conducting field sampling. In addition, we chose to collect more detailed information on tree health status than defined in the protocol.

Details on these methodological interpretations and refinements are described below.

- DBH was read from the side-slope of the tree.
- DBH of the tree was taken at a vertical distance of 1.37 meters in height from the base without regard to the curvature of the tree.
- The 45 degree rule for determining whether it was a tree or a branch was read from the base of the clump to the height at DBH of the tree/branch in question.
- Slope of the plot was taken as the average of the slope looking up and down along the aspect from plot center.
- Plot elevation was recorded from the SW corner.
- In early season plots, seasonal/self-pruning kill was recorded as crown kill. Some crewmembers continued this through the season.
- Crown kill was recorded for all trees, not just PIAL and PIBA.
- Although not stated in the protocol, the crew recorded tree damage such as: dead top, bark damage, snow mold, and flat top. These were recorded in the comments section in the database next to the individual tree.
- Trees that were “dead” were recorded with no kill, the crown kill was left blank in the datasheet. Trees that were “recent dead” were recorded as 100% crown kill for all sections.
- The crew read seedlings from the South line for plots 1 -3, from 20 m line (@20 meters on the North line) for plots 4 -6, and from 40 m line (@ 40 meters on the North line). All these lines were always run from the West to East to ensure that it would be repeatable; to be consistent re-reads in Panel 3 should follow this protocol. In the event that any of these lines were longer than 50 meters, seedling plots 3, 4, and 9 were always read from 44 – 47 meters (rather than 3 meters in from the east line).
- All GPS corner points were averaged for at least 300 points.
- Many of the krummholz trees were tagged low on the stem, so that the tag would not fall off over winter. All DBH’s will have to be re-determined in krummholz plots.
- Unlike 2013, RD trees were recorded only as such, no mortality year was recorded.
- Plots were rejected for steepness for plots consistently >35 degrees (as opposed to >30 degrees in 2013)
- Data on presence of cones was collected for all tree species, but only entered for PINALB or PINBAL in the database.

Appendix 2. Plot Status and Location

Table A-1. List of sampling locations for white pine monitoring plots in the SIEN. The column EvalStatus indicates whether a site was established, dropped because it was non-target, or if it was not established (not visited) in the field. For sites that were visited, they are listed as either “Incomplete” indicating that not all subplots have been finished or completed. If the plot was completed, the year it was fully installed is listed. Note that UTM X and UTM Y coordinates for established plots are the plot corner 1 (SW corner) coordinates as established in the field, and no longer match exactly the coordinates produced by the GRTS algorithm used to navigate to the plot during initial set-up.

Park-Species	Plot ID	UTM X	UTM Y	Panel	EvalStatus	EvalNotes
YOSE-PIAL	01	272730	4211038	Panel_1x	Dropped	>35_Slope
YOSE-PIAL	02	288803	4213209	Panel_1	Not Established	
YOSE-PIAL	03	296088	4182250	Panel_1	2011	
YOSE-PIAL	04	290567	4185341	Panel_1	2011	
YOSE-PIAL	05	285267	4218542	Panel_1x	Dropped	No trees
YOSE-PIAL	06	279028	4195054	Panel_1	Not Established	
YOSE-PIAL	07	286332	4191015	Panel_1	2011	
YOSE-PIAL	08	295120	4177650	Panel_1	2011	
YOSE-PIAL	09	289361	4208460	Panel_1x	Dropped	>35_Slope
YOSE-PIAL	10	296034	4197576	Panel_1	2011	
YOSE-PIAL	11	265845	4218338	Panel_1	Not Established	
YOSE-PIAL	12	265845	4218338	Panel_1x	Dropped	No trees
YOSE-PIAL	13	290527	4215554	Panel_1x	Dropped	>35_Slope
YOSE-PIAL	14	298862	4191734	Panel_1	2011	
YOSE-PIAL	15	294711	4185917	Panel_1	2011	
YOSE-PIAL	16	268730	4223677	Panel_1	Not Established	
YOSE-PIAL	17	272205	4217495	Panel_1x	Dropped	>35_Slope
YOSE-PIAL	18	295937	4212170	Panel_1	2013	
YOSE-PIAL	19	303605	4189886	Panel_2	2014	
YOSE-PIAL	20	286082	4173212	Panel_2	2013	
YOSE-PIAL	21	284547	4213602	Panel_2	Incomplete	Subplots 1 & 2 only
YOSE-PIAL	22	303861	4191215	Panel_2	2013	
YOSE-PIAL	23	290671	4198498	Panel_2x	Dropped	No Trees

Park-Species	Plot ID	UTM X	UTM Y	Panel	EvalStatus	EvalNotes
YOSE-PIAL	24	296891	4175231	Panel_2	2013	
YOSE-PIAL	25	293052	4208800	Panel_2	2013	
YOSE-PIAL	26	300265	4196210	Panel_2	2013	
YOSE-PIAL	27	292618	4193551	Panel_2x	Dropped	No Trees
YOSE-PIAL	28	287655	4220242	Panel_2x	Dropped	No Route
YOSE-PIAL	29	288002	4215672	Panel_2x	Dropped	>35_Slope
YOSE-PIAL	30	297811	4192202	Panel_2x	Dropped	No Trees
YOSE-PIAL	31	292132	4186649	Panel_2	2014	
YOSE-PIAL	32	282831	4220099	Panel_2	2014	
YOSE-PIAL	33	281485	4206089	Panel_2x	Dropped	>35_Slope
YOSE-PIAL	34	295896	4203615	Panel_2x	Dropped	>35_Slope
YOSE-PIAL	35	300685	4188869	Panel_2	2014	
YOSE-PIAL	36	286581	4174238	Panel_2	2014	
YOSE-PIAL	37	282114	4211493	Panel_2x	Dropped	>35_Slope
YOSE-PIAL	38	302534	4193310	Panel_2	2014	
YOSE-PIAL	39	291731	4196540	Panel_3x	Dropped	No Trees
YOSE-PIAL	40	296396	4178608	Panel_3	2014	
YOSE-PIAL	41	292441	4201020	Panel_3	Not Established	
YOSE-PIAL	42	301791	4196147	Panel_3	2014	
YOSE-PIAL	43	294453	4183421	Panel_3	2014	
YOSE-PIAL	44	276329	4225930	Panel_3	Not Established	
YOSE-PIAL	45	294473	4210376	Panel_3x	Dropped	>35_Slope
YOSE-PIAL	46	298760	4187833	Panel_3	Not Established	
YOSE-PIAL	47	288739	4186425	Panel_3x	Dropped	>35_Slope
YOSE-PIAL	48	278555	4224311	Panel_3	Not Established	
YOSE-PIAL	49	285782	4214700	Panel_3	2011	
YOSE-PIAL	50	279271	4196291	Panel_3x	Dropped	No Trees
YOSE-PIAL	51	302368	4185091	Panel_3	Not Established	
YOSE-PIAL	52	294465	4174505	Panel_3	2011	
YOSE-PIAL	53	280552	4217599	Panel_3	2011	

Park-Species	Plot ID	UTM X	UTM Y	Panel	EvalStatus	EvalNotes
YOSE-PIAL	54	297249	4199689	Panel_3	2011	
SEKI-PIAL	01	367290	4027141	Panel_1	Not Established	
SEKI-PIAL	02	345651	4118343	Panel_1	2014	
SEKI-PIAL	03	374534	4075809	Panel_1	Not Established	
SEKI-PIAL	04	375908	4084191	Panel_1	Not Established	
SEKI-PIAL	05	372907	4093446	Panel_1	Not Established	
SEKI-PIAL	06	343590	4112006	Panel_1x	Dropped	>35_Slope
SEKI-PIAL	07	368793	4067831	Panel_1x	Dropped	>35_Slope
SEKI-PIAL	08	357644	4085977	Panel_1	Not Established	
SEKI-PIAL	09	366236	4101569	Panel_1x	Dropped	>35_Slope
SEKI-PIAL	10	364469	4059015	Panel_1	Not Established	
SEKI-PIAL	11	372567	4075392	Panel_1	Not Established	
SEKI-PIAL	12	357557	4083750	Panel_1	2014	
SEKI-PIAL	13	360382	4105787	Panel_1	Not Established	
SEKI-PIAL	14	376492	4057576	Panel_1x	Dropped	No Trees
SEKI-PIAL	15	368275	4091574	Panel_1	Not Established	
SEKI-PIAL	16	356989	4077572	Panel_1x	Dropped	>35_Slope
SEKI-PIAL	17	362761	4033663	Panel_1	Not Established	
SEKI-PIAL	18	343283	4112827	Panel_2	Incomplete	Subplots1 – 3 only
SEKI-PIAL	19	375619	4074608	Panel_2x	Dropped	>35_Slope
SEKI-PIAL	20	361155	4084009	Panel_2	2013	
SEKI-PIAL	21	371958	4097865	Panel_2x	Dropped	>35_Slope
SEKI-PIAL	22	351408	4095437	Panel_2x	Dropped	No Route
SEKI-PIAL	23	372112	4065836	Panel_2x	Dropped	>35_Slope
SEKI-PIAL	24	358026	4089119	Panel_2	2013	
SEKI-PIAL	25	365621	4094633	Panel_2	2013	
SEKI-PIAL	26	355753	4057139	Panel_2x	Dropped	No Trees
SEKI-PIAL	27	367661	4072341	Panel_2	2013	
SEKI-PIAL	28	361949	4091581	Panel_2	2013	
SEKI-PIAL	29	357722	4109427	Panel_2x	Dropped	>35_Slope

Park-Species	Plot ID	UTM X	UTM Y	Panel	EvalStatus	EvalNotes
SEKI-PIAL	30	367938	4039738	Panel_2x	Dropped	No Trees
SEKI-PIAL	31	368793	4083219	Panel_2	Incomplete	Subplots 1 – 2 only
SEKI-PIAL	32	365839	4066495	Panel_2x	Dropped	>35_Slope
SEKI-PIAL	33	339897	4121834	Panel_2	2014	
SEKI-PIAL	34	345544	4113490	Panel_2x	Dropped	>35_Slope
SEKI-PIAL	35	376672	4068290	Panel_2x	Dropped	>35_Slope
SEKI-PIAL	36	362322	4084241	Panel_2x	Dropped	>35_Slope
SEKI-PIAL	37	361596	4104498	Panel_2x	Dropped	No Route
SEKI-PIAL	38	346720	4094780	Panel_2	2014	
SEKI-PIAL	39	372095	4070727	Panel_2x	Dropped	>35_Slope
SEKI-PIAL	40	354109	4085347	Panel_2x	Dropped	No Trees
SEKI-PIAL	41	363987	4095543	Panel_2x	Dropped	>35_Slope
SEKI-PIAL	42	361901	4057273	Panel_2x	Dropped	No Route
SEKI-PIAL	43	372447	4072712	Panel_2	2014	
SEKI-PIAL	44	360112	4088754	Panel_2	2014	
SEKI-PIAL	45	347366	4115429	Panel_2	2014	
SEKI-PIAL	46	370788	4038875	Panel_3x	Dropped	No Trees
SEKI-PIAL	47	372218	4084481	Panel_3x	Dropped	>35_Slope
SEKI-PIAL	48	347886	4081797	Panel_3	2014	
SEKI-PIAL	49	367097	4094696	Panel_3	2014	
SEKI-PIAL	50	342764	4117298	Panel_3x	Dropped	>35_Slope
SEKI-PIAL	51	376111	4070297	Panel_3	2014	
SEKI-PIAL	52	364852	4084028	Panel_3	Not Established	
SEKI-PIAL	53	363263	4099360	Panel_3	Not Established	
SEKI-PIAL	54	338892	4118855	Panel_3	Not Established	
SEKI-PIAL	55	368946	4075659	Panel_3x	Dropped	>35_Slope
SEKI-PIAL	56	359700	4080686	Panel_3x	Dropped	>35_Slope
SEKI-PIAL	57	359051	4104460	Panel_3x	Dropped	No Route
SEKI-PIAL	58	372709	4063450	Panel_3	Not Established	
SEKI-PIAL	59	372495	4091307	Panel_3	Not Established	

Park-Species	Plot ID	UTM X	UTM Y	Panel	EvalStatus	EvalNotes
SEKI-PIAL	60	361751	4085403	Panel_3	Not Established	
SEKI-PIAL	61	348673	4115246	Panel_3	Not Established	
SEKI-PIAL	62	376844	4044787	Panel_3	Not Established	
SEKI-PIAL	63	371096	4080482	Panel_3x	Dropped	>35_Slope
SEKI-PIAL	64	349766	4082680	Panel_3x	Dropped	>35_Slope
SEKI-PIAL	65	348874	4112395	Panel_3	Not Established	
SEKI-PIBA	01	355125	4029380	Panel_1	Not Established	
SEKI-PIBA	02	375721	4039069	Panel_1	2011	
SEKI-PIBA	03	363290	4043329	Panel_1	Not Established	
SEKI-PIBA	04	362613	4067179	Panel_1	Not Established	
SEKI-PIBA	05	370614	4026162	Panel_1	No Established	
SEKI-PIBA	06	376988	4042810	Panel_1	2011	
SEKI-PIBA	07	374789	4056572	Panel_1	2011	
SEKI-PIBA	08	362507	4062625	Panel_1	Not Established	
SEKI-PIBA	09	377826	4033520	Panel_1	2011	
SEKI-PIBA	10	380915	4038349	Panel_1	2011	
SEKI-PIBA	11	375675	4050116	Panel_1	2011	
SEKI-PIBA	12	367913	4076907	Panel_1x	Dropped	No Trees
SEKI-PIBA	13	363692	4033498	Panel_1x	Dropped	>35_Slope
SEKI-PIBA	14	366283	4038676	Panel_1x	Dropped	>35_Slope
SEKI-PIBA	15	386345	4040899	Panel_1	2011	
SEKI-PIBA	16	356739	4061068	Panel_2	2013	
SEKI-PIBA	17	355948	4031543	Panel_2	2013	
SEKI-PIBA	18	375967	4045554	Panel_2	2013	
SEKI-PIBA	19	379846	4047488	Panel_2	2013	
SEKI-PIBA	20	367540	4067377	Panel_2x	Dropped	>35_Slope
SEKI-PIBA	21	375557	4032343	Panel_2	2013	
SEKI-PIBA	22	380284	4042853	Panel_2	2013	
SEKI-PIBA	23	374094	4056105	Panel_2	2013	
SEKI-PIBA	24	362018	4059269	Panel_2	Not Established	

Park-Species	Plot ID	UTM X	UTM Y	Panel	EvalStatus	EvalNotes
SEKI-PIBA	25	369054	4032210	Panel_2	2013	
SEKI-PIBA	26	371355	4046767	Panel_2	Not Established	
SEKI-PIBA	27	372176	4051432	Panel_2	Incomplete	Subplots 1 – 2 only
SEKI-PIBA	28	373060	4084548	Panel_2x	Dropped	>35_Slope
SEKI-PIBA	29	364439	4034149	Panel_2	2013	
SEKI-PIBA	30	371006	4042667	Panel_3	2014	
SEKI-PIBA	31	386287	4038225	Panel_3	2014	
SEKI-PIBA	32	360362	4059458	Panel_3x	Dropped	>35_Slope
SEKI-PIBA	33	384714	4036309	Panel_3	2014	
SEKI-PIBA	34	373202	4045338	Panel_3	Not Established	
SEKI-PIBA	35	377887	4048446	Panel_3	2014	
SEKI-PIBA	36	373289	4057861	Panel_3	2014	
SEKI-PIBA	37	376739	4029729	Panel_3	2014	
SEKI-PIBA	38	376735	4036915	Panel_3	2014	
SEKI-PIBA	39	375604	4053148	Panel_3	2014	
SEKI-PIBA	40	371733	4071478	Panel_3	2014	
SEKI-PIBA	41	367280	4034622	Panel_3	2014	
SEKI-PIBA	42	369440	4050366	Panel_3	Not Established	

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
U.S. Department of the Interior



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